Effect of Using Polypropylene Fibers on the Mechanical Properties of Asphalt Mixture

Wali Murad Kalhoro, Naeem Aziz Memon, Touqeer Ali Rind, Muhammad Farooque, Muhammad Arif, Ali Murad

Abstract- Flexible pavement consists of different layers. These layers contain bitumen substances, which together with the aggregate are arranged to reduce cohesion from top to bottom. The problems related with the flexible pavements are their premature distress in the form of cracks, instability, raveling, surface undulations and segregation. These results in huge maintenance cost. To minimize the maintenance cost, the proper quality of work and material are needed. There are several kinds of fiber materials are available in the market such as carbon fiber, glass fiber, polyester fiber, polypropylene fiber, etc. In this research an attempt has been made to use polypropylene fiber in asphalt mixture. Different percentages were used from 0.5%, 1%, 1.5%, 2%, 2.5%, 3%, 3.5%, 4%, 4.5%, and 5% polypropylene fiber of 12mm long in asphalt mixture by total aggregates mixture at 4% optimum bitumen binder. The Marshall Stability test was conducted to analyze the behavior of asphalt mixture in terms of stability and flow. The results indicate that the addition of polypropylene fibers increases the stability. As the percentage of polypropylene fibersincreases the stability of modified asphalt mixture increases, and the flow value decreases. Further study can be carried out by determining other mechanical properties.

Index Terms— Flexible Pavement, Hot Mix Asphalt, Polypropylene Fiber, Optimum Asphalt Content, Stability, Flow.

1 INTRODUCTION

Mobility is the fundamental human being need. Since the beginning era of humanity, many peoples travel for trade, commerce, social and personal fulfillment. The primary need for the transportation is the economy. The cost, speed and capacity of available transportation have the wide effect on the economy of the country. An examination of most developed nations indicates that they have been renowned for their competent transportation systems and services. However, in period of globalization the focus has not only been given to development rather the sustainable development. By the passage of time the consumption of resources is severely increased resulting in inundation of quality and quantity of resources. To overcome the transportation needs much research are conducted to extend the quality and quantity of services. So far, roads are key source of transport, many studies are included for roads development. Principally, there are two pavements Black top i.e., Flexible pavement and white top i.e., rigid pavement.

Flexible Pavement also acknowledged as asphalt, or blacktop pavement is combination of various layers superimposed on each other. The pattern of load transfer is layer wise by the graingrain-to-grainact of particles. It has been used since ancient times and major part of roads about 95% consists of this type of the pavements, because of their easiness in construction, less initial & maintenance cost in comparison with the rigid pavement. Layer wise a flexible pavement consists of Subbase, base course, and wearing course layers. On the surface or wearing course vertical compressive stress is maximum and is equal to contact pressure because of its direct contact with tires. Therefore, it should be made strongest among all layers, while other layers could be made by inferior material with lower cost because they take only little amount of stresses as there is no straight wearing exploit due to travel loads on them.

Common causes of road degradation and degradation include overloading, sagging, poor drainage, lack road maintenance, lack of proper design, poor weather conditions Polypropylene fiber (FF) is used as an additive in asphalt mixes to overcome these problems and achieve greater stability and flow value. The subject of our study is "Modified bitumen (a modifier using polypropylene fiber) using asphalt mix design for base course".

Polypropylene fiber(PPF) is a 100% synthetic fiber made up of 85% monomer 'Propylene (C3H6)' which is a hydrocarbon.Having high molecular mode and weight, the propylene polymerizes to produce polypropylene fibers with very useful properties like excellent resistant to chemicals, alkalis and acids, less moisture absorption, lowest density, and lower conductivity in comparison to other synthetic fibers.There are different type of variety in polypropylene fibers based on their density, length, diameter, and strength (Modulus of elasticity) are shown in Table 1.

Table 1 Different types of polypropylene fiber [1]

- *Wali Murad is currently pursuing master's degree program in civil engineering in Mehran UET SZABC Khairpur Mirs, Sindh, Pakistan E-mail: walimurad.kalhoro@gmail.com*
- *Naeem Aziz Memon is currently serving as a Associat Professor of Mehran UET Jamshoro, Sindh, Pakistan*
- *E-mail: naeem.aziz@faculty.muet.edu.pk*
- *Touqeer Ali Rind is currently serving as a Lecturer at Civil Engineering Dept, Mehran UET SZABC Khairpur Mirs, Sindh, Pakistan*
- *E-mail: touqeerali@muetkhp.edu.pk*
- *Muhammad Farooque is currently pursuing master's degree program in civil engineering in Mehran UET SZABC Khairpur Mirs, Sindh, Pakistan*
- *E-mail: muhammadfarooq.panhyar@gmail.com*
- *Muhammad Arif is currently working as an Incharge Resident Engineer at Cadet College Karampur, Kandhkot, Sindh, Pakistan E-mail: arifali.panhyar@gmail.com*
- *Ali Murad is currently working as a Site Engineer in RCC Consultant, Jacobabad, Sindh, Pakistan E-mail: mir.ali178@gmail.com*

Fiber type	(L) mm	Dia mm	TSMPa	Elastic Modulus (GPa)	Sp. Surface Area (m^2/kg)	Density (kg/cm^3)	Fiber type
Monofilament	30 to 50	0.30 to 0.35	547 to 658	3.50 to 7.50	91	0.90	Monofilament
Microfilament	12 to 20	0.05 to 0.20	330 to 414	3.70 to 5.50	225	0.91	Microfilament
Fibrillated	19 to 40	0.20 to 0.30	500 to 750	5.00 to 10.00	58	0.95	Fibrillated

Polypropylene fiber is utilized in the construction industry as an auxiliary reinforcement that catches cracks, builds quality and protection from effect and friction, and significantly improves construction quality. Polypropylene is a thermoplastic polymer utilized in an assortment of utilizations. Polypropylene fiber has all the exceptional properties related with polypropylene polymer.

Polypropylene fibers were also utilized in the United States as modifiers of asphalt concrete. A standard for the use of polypropylene fibers in high-performance asphalt concrete has been published by the Ohio State Department of Transportation (ODOT) [2]. A detailed instruction provided by the Standard, on the preparation, composition, and compression of asphalt concrete with polypropylene fibers. As per this standard, superior hot blend asphalt concrete aggregate comprises of bitumen and polypropylene filaments. Aggregates and bitumen should conform to ODOT properties. The mixture should contain the required number of polypropylene fibers. Polypropylene filaments ought to be exceptionally formulated for use in asphalt concrete blends. The fibers should be as per the producer's description; they should be of the same type and standard color and should be in accordance with the requirements.

Marshall Stability value increases by adding polypropylene fiber in a dry basis of asphalt mixture and the flow values decreases and the fatigue life of the pavement increases [3]. The polypropylene fibers increase the stiffness of bitumen results in more stiff mixtures with reduced drain-down and fatigue life increased [4]. The polypropylene fiber addition into asphalt mixture has shown the Marshal Flow value decreased (38%), stability values increases (26.3%) and air voids increases (67.5%) [5].

2 LITERATURE REVIEW

This research paper was about the Polypropylene Fibre (PPF) effect on engineering properties of bitumen and bituminous mix. Few tests on bituminous mixes were also performed to adjudge the effect of different percentages of fibers on mixes. Marshall Stability test were determined for optimum binder content. By altering the quantity of 20mm polypropylene fibers (3%, 5%, and 7% by weight of bitumen), optimum result was obtained. It has been found that due to the addition of polypropylene fiber, stability value increased, and flow value decreased. It was observed that the optimum result of polypropylene fiber was determined at 5% by weight of bitumen. Modified bituminous concrete with 4.5% bitumen and 5% polypropylene fibre increased the stability value by about 40%. Softening point increased by 35% than that of conventional bitumen. Ductility decreased by 17% than that of unmodified bitumen. Penetration decreased by 5% than that of unmodified bitumen. As a result of 5% addition of polypropylene fiber to bituminous mixture increased the Marshall stability value and decreased the flow value but within prescribed limits specified in the design procedure. Increase in fibre content more than 5% resulted in not much variation in stability or flow value **[6]**.

This research paper was about the environmental effect on polypropylene fiber used in hot mix asphalt. Due to different aggressive environmental condition an investigation has been made to minimize the deterioration which caused damage therefore polypropylene fiber was used in different ratios like (0, 5, 7.5 and 10% by weight of binder in hot mix asphalt) then these mixtures were kept for certain period in a solution of freeze-thaw cycling cabinet, Na2SO4, NaCl, CaCl2. It has been found that stability increased with content up to 7.5% of fiber reinforced and then dropped by 10% of fiber reinforced mixtures and solution of freeze-thaw cycling was found as harmless and solution of Na2SO4 was found as harmful among other environments in this investigation **[7]**.

This research paper was about the properties of hybrid steel and polypropylene fiber reinforced concrete composite.Three different specimens of FRC mix proportion and one conventional specimen were casted such as (a) 75% SF, (b) 75% SF + 25% PPF, (c) 25% PPF, and (d) 0% fibre for conventional. In this period the volume fraction of fiber reinforced concrete was fixed at 1.5% and the strength of concrete was designed to achieve at 28 days for C60. It has been found that by using the fibers in concrete decreased the workability. Also, concrete blend with both SF and PPF created the huge splitting tensile and flexural strengths with increase of 75.9% and 86.5%, respectively as compared with the conventional **[8].**

This research paper was about the Rutting performance of polypropylene modified asphalt concrete. Two types of

samples of asphalt concrete were taken such as conventional sample (without addition of polypropylene) and modified sample (with addition of polypropylene). Marshall Mix Design was utilized for deciding the Optimum Asphalt Content for both samples. Concrete specimens were prepared of dimension of 300mm length and breadth and 50mm thickness for both samples. Then, those samples were tested in a wheel tracking device. Those samples were tested at fourtemperature i.e. 40°C, 50°C, 55°C and 60°C. Under the loading of 10000 passes of 700N pivot load. It has been found that polypropylene fiber increases the Marshall stability by 25% **[9]**.

This research paper was about the impact of polypropylene fiber on the break properties of cement treated crushed rock (CTCR), CTCR is a cementitious asphalt composite material made of cement, crushed rocks and water The crack segment increased consistently, and the fracture connection chart is getting plumper and plumper when it comes to from 0% to 0.1%. Likewise, the ability of polypropylene fiber to oppose the breaking phenomena of CTCR are getting stronger with an addition of fiber content **[10]**.

This research paper was about the Use of Polypropylene Fibres to overcome the effects of rutting on asphalt pavement in Pakistan. The wet method was adopted in which polypropylene fibers were added in Hot Mix Asphalt i.e. before added to aggregate these fibers were heated and mixed with asphalt binder. It was taken about 0.5% by weight of aggregate. Marshall samples were made of five different asphalt content like 3.5%, 4.0%, 4.5%, 5.0% and 5.5%. Total number of samples was fifty (50) in which polypropylene fibers were used in 25 samples and other 25 samples are without it. It has been found that there was a reduction in rut depth and increment in resilient modulus by addition of fibers at extreme temperature. And it was also found that the use of polypropylene fibers is economically feasible at high temperature **[11].**

This research paper was about the influence of polypropylene fiber and silica fume on the fracture properties of concrete composite consist of fly ash. These additives are used as a mix of polypropylene fiber with content from 0.04 to 0.12% by volume and silica fume from 3 to 12% by mass with 15% of fly ash by mass. fly ash and silica fume were added by changing the similar amount of cement in concrete composite and polypropylene fiber was added with amount of cementitious unchanged materials in concrete. When the quantity of silica fume increases from 0 to 3%, then fracture components increases however fracture parameter start to decrease when it exceeds from 3%. When the quantity of polypropylene fiber increases from 0 to 0.12%, then the different fracture components increases however fracture parameter start to decrease when it exceeds from 0.12% **[12].**

This research paper was about, the polypropylene additive was choosen as additive fiber because of minimum cost situation and asphalt pavement have a good relation according to various studies. three different types of percentages (0.1%, 0.2%, and 0.3%) were used of length {6mm and 12mm} in asphalt concrete mixture As a result of adding polypropylene the stability increased by {26%} and flow value decreased by {38%} **[13]**.

This research paper concerned the impact of polypropylene fibers on the efficiency of asphalts. This research paper discusses the asphalt concrete with rate 0.3%, 0.5% and 1% of polypropylene fibers were examined. Flow tests and Marshall Stability tests were used, the increase in Martial Stability Index was observed when the content of polypropylene fiber increased by 1% for samples of polypropylene fibers, which is more than 58%. According to the results of the test, the inclusion of 1% in polypropylene fibers prolongs the fatigue period by 27% **[14]**.

3 MATERIALS

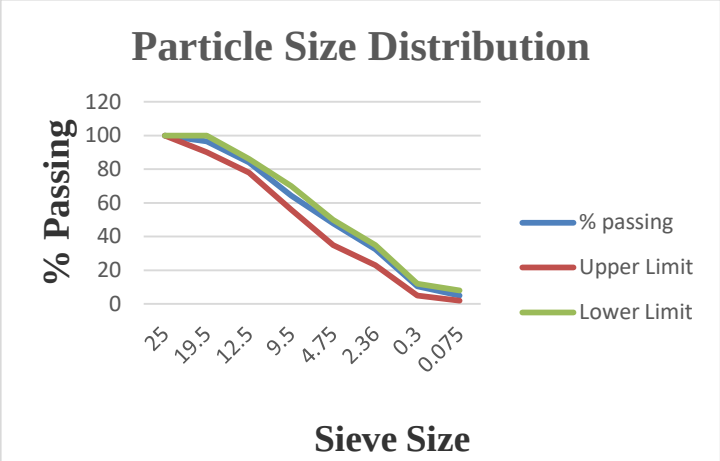
Each material constitute is used to manufacture the PPF laboratory specimens is described below:

3.1 Aggregates

Aggregates can be defined as any hard, inert mineral that is used to mix graduate particles. The total amount of percentage in asphalt mixture is usually 75-78% by volume and 90-95% by weight. As aggregate is mainly responsible to bear the loads on the pavement; the crushed aggregates were collected from Kot Bungalow KhairpurMirs District of Sindh, Pakistan which was used in this study. The aggregate gradation was selected according to the job mix formula. The following tables 2 and 3 shows the blending of aggregates and combined specific gravities of aggregates used in this research.

Table 2 Blending of Aggregates Used for Asphalt Mix design

Material	Total Blend	Target Value	Specification
25mm	100	100	100
19.5mm	96.45	95	90-100
12.5mm	83.96	82	78-86
9.5mm	64.34	63	56-70
4.75mm	47.86	42.5	35-50
2.36mm	32.40	29	23-35
300μm	10.51	8.5	5-12
0.075μm	4.94	5	2-8



Graph 1 Particle size distribution curve

Table 3 Combined Specific Gravities of Aggregates

Aggregate Size	% Used	Bulk Sp. Gr. Aggregate Average	App. Sp. Gr. Aggregate Average
25 ~ 19 mm	15	2.663	2.714
19 ~ 4.75 mm	37	2.659	2.711
4.75 ~ 0.075 mm	48	2.651	2.707

Combined Bulk Specific Gravity of Aggregate

Gsb = 2.656

Combined Apparent Specific Gravity of Aggregate

Gsa =2.710

3.2 Bitumen

The asphalt used in the production of asphalt mix for all normal and modified (poly propylene) specimens was a paving grade 60/70 which was arranged from a batching plant a site nearby Hyderabad, Sindh.

Table 4 Laboratory Test Results of Bitumen

Laboratory Test	Results
Penetration (AASHTO T-49, ASTM D-5)	66
Ductility (AASHTO T-51, ASTM D-113)	140 cm
Softening point (AASHTO T-53, ASTM D-36)	53 °C
Specific gravity (AASHTO T-288, ASTM D-70)	1.030 Kg/cc
Flash and fire point (AASHTO T-48, ASTM D-92) 1) Flash point 2) Fire point	 310 °C 368 °C

3.3 Polypropylene Fibers

It is a compound of thermoplastic which used in civil engineering works. It is composed of chain growth of monomer propylene and chemical formula of polypropylene fiber is $(C_3H_6)_n$. Polypropylene fibers (PPF) are used as a asphalt additive to increase its strength and reduce cracking.

In this thesis work we are using 6mm fiber diameter and 18mm fiber length.

Table 5 Physical properties of Poly propylene Fiber [15]

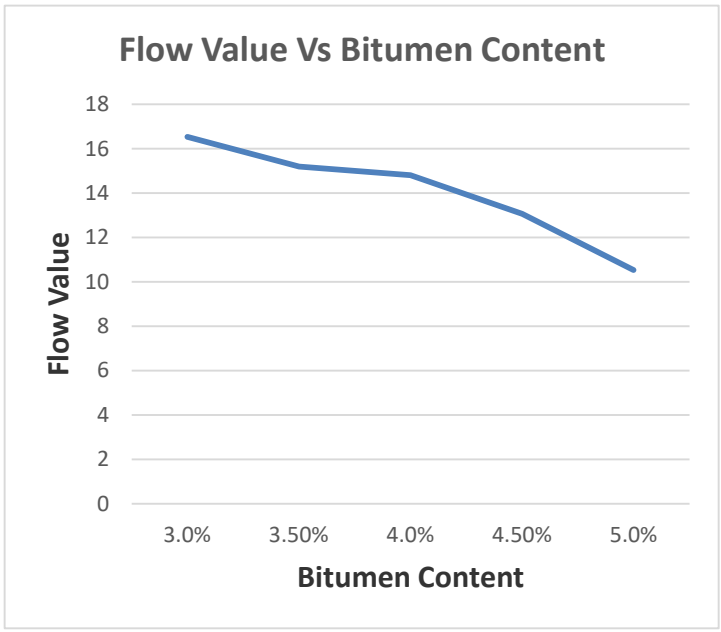
Tensile strength (gf/den)	3.5 to 5.5
Elongation (%)	40 to 100
Abrasion resistance	Good
Moisture absorption (%)	0 to 0.05
Softening point (ºC)	140
Melting point (ºC)	165
Chemical resistance	Generally Excellent
Relative density	0.91
Thermal conductivity	6.0 (with air is 1.0)
Electric insulation	Excellent
Resistance to mildew	Excellent

4 Sample Preparation

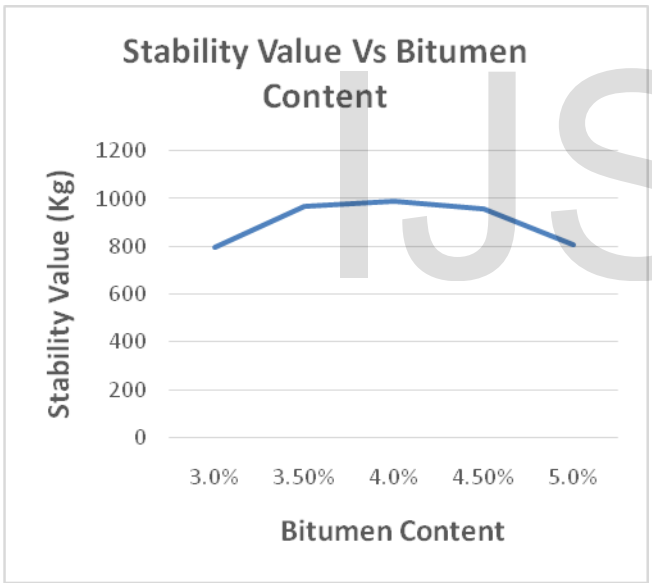
In this process, polypropylene fiber is mixed with hot aggregate at 160 ° C and blended well. Polypropylene is evenly coated on the aggregate surface and then hot bitumen grade 60/70 is added in it and thoroughly mixed until black layer of bitumen is coated over aggregate. In this research an attempt has been made to use polypropylene fiber in asphalt mixture. Different percentages were used from 0.5%, 1%, 1.5%, 2%, 2.5%, 3%, 3.5%, 4%, 4.5%, and 5% polypropylene fiber of 12mm long in asphalt mixture by total aggregates mixture at 4% optimum bitumen binder. The Marshall Stability test was conducted to have analysis the behavior of asphalt mixture in terms of stability and flow.

Table 6 Results of Marshal Data Sheets from 3% to 5% Bitumen

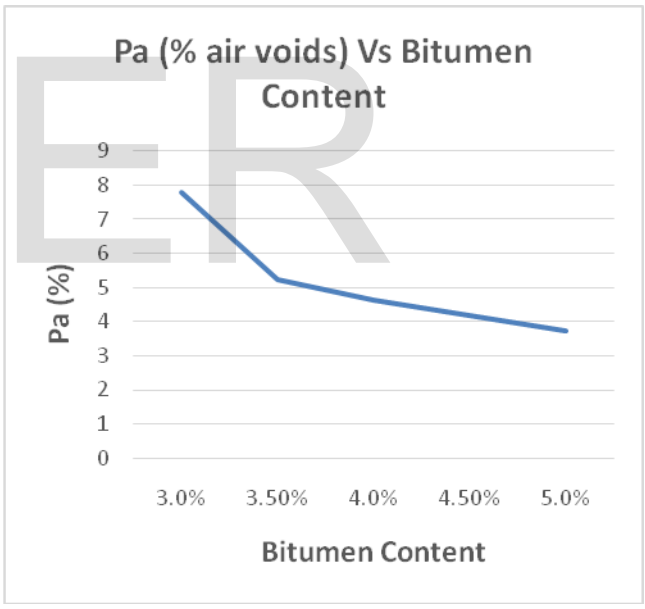
BC %	Gmb	VMA	Pa	VFB	St. Value	Flow Value
3.0	2.361	13.774	7.773	43.568	797.626	16.533
3.50	2.407	12.547	5.236	58.269	968.386	15.2
4.0	2.404	13.108	4.641	64.594	988.319	14.8
4.50	2.397	13.813	4.197	69.616	954.373	13.067
5.0	2.391	14.479	3.744	74.142	808.801	10.533



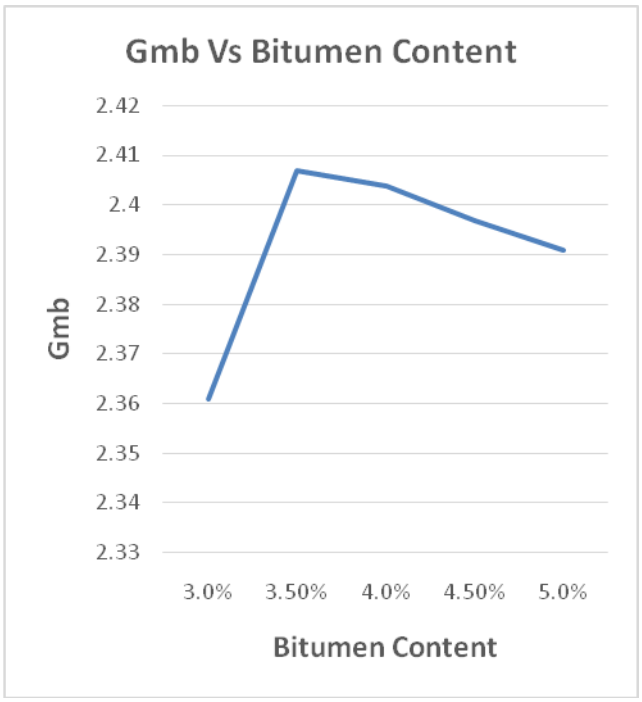
Graph 3 Flow Value Vs Bitumen Content



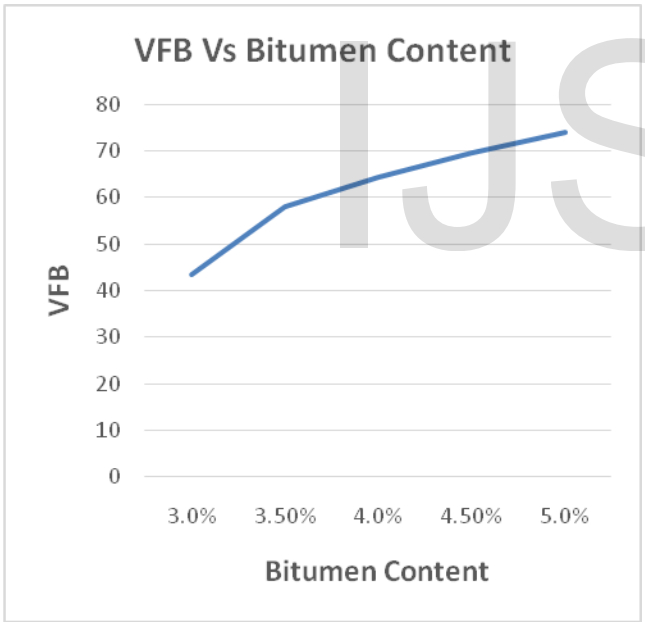
Graph 2 Stability Value Vs Bitumen Content



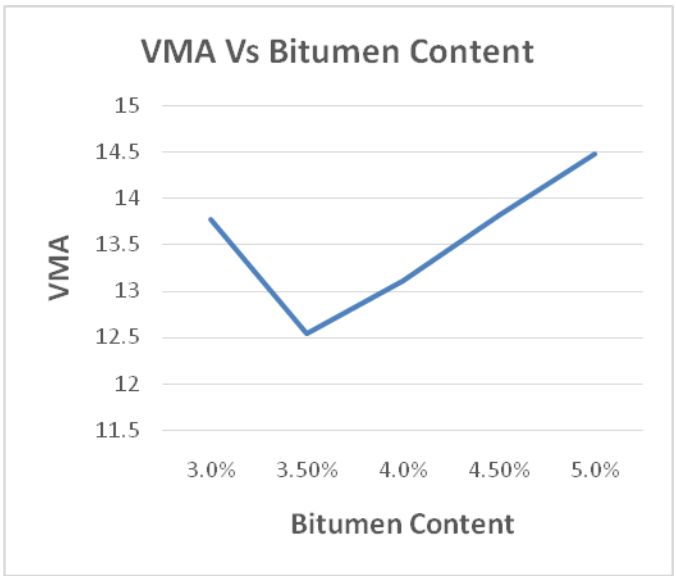
Graph 4 Pa (%) Vs Bitumen Content



Graph 5 Density (Gmb) Vs Bitumen Content



Graph 6 VFB Vs Bitumen Content



Graph 7 VMA Vs Bitumen Content

Optimum Bitumen Content:

B1=Bitumencontentat maximumdensity (unit weight) = 3.65%

B2= Bitumen content atmaximum 4% Air voids = 4.6%

B3= Bitumencontent atmaximum stability = 3.80%

OBC = (B1+B2+B3)/3 = (3.65+4.6+3.8)/3

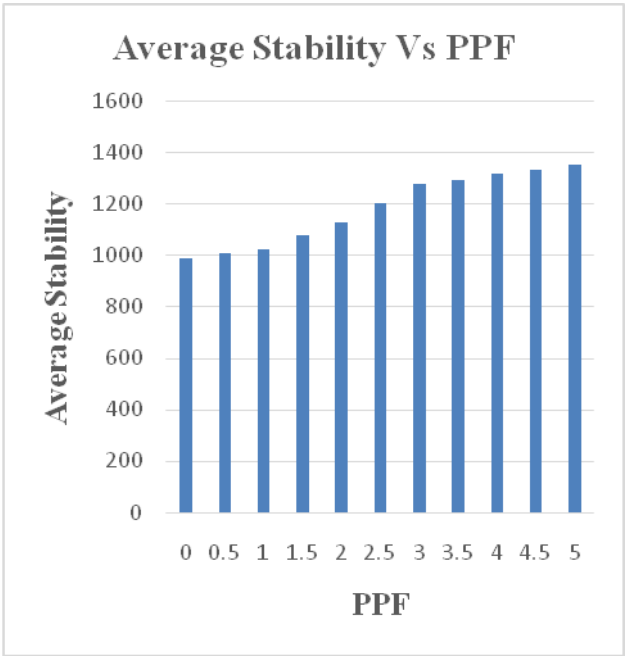
OBC = 4%

5 RESULTS

From above results, the OBC was 4%. While making modification in asphalt mixture, the PP fiber was used from 0.5% to 5% with 0.5% increment at OBC (4%) using the dry process in mix design.

Table 7 Average Stability from 0% PPF to 5% PPF

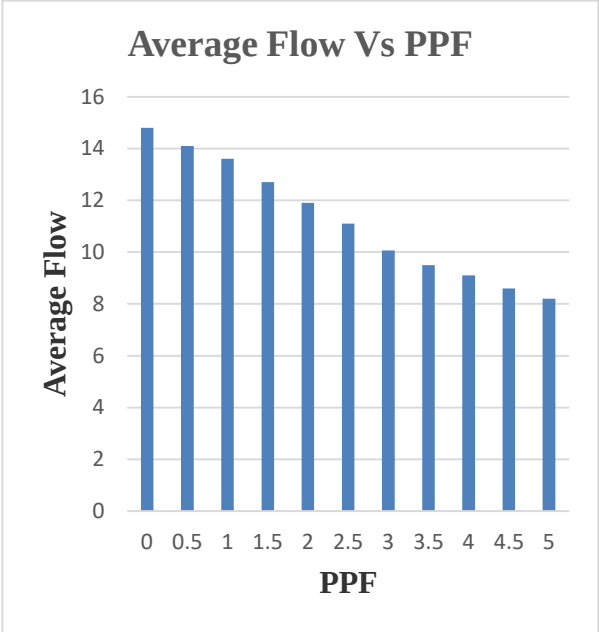
Sample #	% PP	Stability (Kg)	Avg Stability
S-1	0	988.319	988.3
S-2		1024.924	
S-3		951.715	
S-1	0.5	989.8	1007.1
S-2		988.319	
S-3		1043.226	
S-1	1	996.655	1020.8
S-2		1014.776	
S-3		1051.018	
S-1	1.5	1076.387	1076.4
S-2		1112.267	
S-3		1040.508	
S-1	2	1172.066	1124.7
S-2		1101.032	
S-3		1101.032	
S-1	2.5	1243.101	1201.7
S-2		1225.342	
S-3		1136.549	
S-1	3	1252.524	1275.7
S-2		1304.712	
S-3		1269.92	
S-1	3.5	1273.906	1291.1
S-2		1325.551	
S-3		1273.906	
S-1	4	1342.766	1314.1
S-2		1239.476	
S-2		1359.981	
S-1	4.5	1331.35	1331.4
S-2		1297.645	
S-3		1365.055	
S-1	5	1335.699	1352.2
S-2		1319.209	
S-3		1401.659	



Graph 8 Stability vs PPF (Bar Chart)

Table 8 Average Flow from 0% PPF to 5% PPF

Sample #	% PP	Flow (mm)	Avg Flow
S-1	0	14.4	14.8
S-2		15.2	
S-3		14.8	
S-1	0.5	14.6	14.1
S-2		13.8	
S-3		14	
S-1	1	13.2	13.6
S-2		13.2	
S-3		13.2	
S-1	1.5	13	12.7
S-2		13.2	
S-3		12	
S-1	2	12.2	11.9
S-2		11.8	
S-3		11.6	
S-1	2.5	11.2	11.1
S-2		11.8	
S-3		10.2	
S-1	3	9.6	10.07
S-2		10.4	
S-3		10.2	
S-1	3.5	9.4	9.5
S-2		10.2	
S-3		9	
S-1	4	9.2	9.1
S-2		9.4	
S-2		8.8	
S-1	4.5	8.4	8.6
S-2		8.6	
S-3		8.8	
S-1	5	7.8	8.2
S-2		8.6	
S-3		8.2	



Graph 9 Flow vs PPF (Bar Chart)

6 Conclusions & Recommendations

- The test results showed that Poly Propylene Fiber (PPF) can be conventionally used as a modifier for asphalt mixture.
- Polypropylene Fiber (PPF) of 18 mm long with different percentages (0.5%, 1%, 1.5%, 2%, 2.5%, 3%, 3.5%, 4%, 4.5%, and 5%) was used which showed with increasing percentage of fiber, the values of stability increased, and flow values decreased.
- Results showed that, 0.5%, 1%, 1.5%, 2%, 2.5%, 3%, 3.5%, 4%, 4.5%, and 5% addition of PPF showed 1.90%, 3.28%, 8.91%, 13.80%, 21.59%, 29.03%, 30.63%, 32.96%, 34.71%, and 36.82% increase in stability respectively with respect to conventional asphalt mixture.
- According to this study, 5% addition of PPF showed maximum stability value which is 36.82% greater as compared to 0% PPF (normal asphalt samples).
- According to this study, 5% PPF showed minimum flow value which is 44.59% lesser as compared to 0% PPF (normal asphalt samples).
- According to the results of this study, the replacement of polypropylene fibers with total aggregates provides a positive contribution to the performance of asphalt pavements.
- Further research can be carried out by determining other mechanical properties on samples.

- In this study 60/70 grade of bitumen is used, which is more used in hot regions. Further research can be carried out by using different grade of bitumen.

ACKNOWLEDGMENT

Authors are thankful to Mehran University of Engineering & Technology SZAB Campus Khairpur Mirs for providing necessary resources for carrying this research work.

REFERENCES

[1] C. Saketh, J. Patel, M. Rajesh, G. Sadanand, and M. Manoj, "Statistical Analysis of Polypropylene Fiber Reinforced Concrete," International Journal of Advance Research, Ideas and Innovations in Technology, vol. 3, pp. 518-532, 2017.

[2] ITEM 400HS. Standard specification for asphalt concrete-high stress using polypropylene fibers. Ohio Department of Transportation, Construction and Materials Specifications; 1998.

[3] Peng GF, Yang WW, Zhao J, Liu YF, Bian SH, Zhao LH. Explosive spalling and residual mechanical properties of fiber-toughened high-performance concrete subjected to high temperatures. Cement and Concrete Research 2006;36(4):723–7.

[4] Einsfeld RA, Velasco MSL. Fracture parameters for high-performance concrete. Cement and Concrete Research 2006;36(3): 576–83.

[5] M. G. Ebrahimi, "The effect of polypropylene modification on Marshall Stability and flow," Eastern Mediterranean University (EMU), 2010.

[6] VarshaHarne, Anuj Kumar Sharma, Kameshwar Rao Tallapragada and SurbhiMewara; "Effect of Polypropylene Fibre on Engineering Properties of Bitumen and Bituminous Mix", Helix (2020) 10 (1): 116-120.

[7] NiyaziUgurKoçkal and SevilKöftecib; "Aggressive Environmental Effect on Polypropylene Fibre Reinforced Hot Mix Asphalt", Procedia Engineering 161 (2016) 963 – 969.

[8] Wan Amizah Wan Jusoh, Izni Syahrizal Ibrahim, Abdul Rahman Mohd Sam, Noor Nabilah Sarbini; "Mechanical and Shrinkage Properties of Hybrid Steel and Polypropylene Fibre Reinforced Concrete Composite", Jurnal Teknologi (Sciences & Engineering) 78:9 (2016) 93–103.

[9] A. Qadir; "Rutting performance of polypropylene modified asphalt concrete", International Journal of Civil Engineering, Vol. 12, No. 3, Transaction A: Civil Engineering, September 2014.

[10] Peng Zhang, Chen-hui Liu, Qing-fu Li, Tian-hang Zhang; "Effect of polypropylene fiber on fracture properties of cement treated crushed rock", Composites: Part B 55 (2013) 48–54.

[11] Adnan Qadir and Shoaib Mohammad Quraishi; "Use of Polypropylene Fibres for Control of Asphalt Pavement's rutting in Pakistan", Department of Urban and Infrastructure Engineering NED University of Engineering and Technology July 2012.

[12] Peng Zhang, Qingfu Li and Zhenhua Sun; "Influence of silica fume and polypropylene fiber on fracture properties of concrete composite containing fly ash", Journal of Reinforced Plastics and Composites 2011 30: 1977 originally published online 1 December 2011.

[13] M. G. Ebrahimi, "The effect of polypropylene modification on Marshall Stability and flow," Eastern Mediterranean University (EMU), 2010.

[14] SerkanTapkın; "The effect of polypropylene fibers on asphalt performance", Building and Environment 43 (2008) 1065–1071.

[15] Veeramani M, Venkatesh K, Vijay R, Antony GV, Karthick R. EXPERIMENTAL STUDY ON THE BEHAVIOUR OF FLEXIBLE PAVEMENT WITH POLYPROPYLENE FIBER. METHODOLOGY. 2019 Mar;6(03).